

## **Coastal Erosion and Land Loss Around the United States: Strategies to Manage and Protect Coastal Resources- Examples from Louisiana**

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The following two papers are provided as background reading. The first paper is taken from a longer paper titled "Coastal and Marine Processes" authored by S J Williams, currently in press as chapter 1.1.3.2 of the UNESCO Encyclopedia of Life Support Systems (EOLSS).

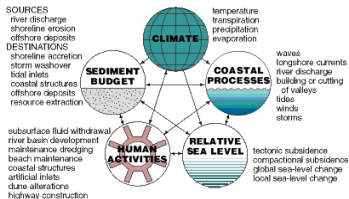
The second is an abstract by S Penland and S J Williams to be presented at the annual mtg. of the Geological Society of America, November 2001, Boston at technical session no. 32 titled : "America's Coastal Crisis---".

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Paper no.1

### **COASTAL and MARINE GEOLOGIC FRAMEWORK and PROCESSES**

#### **SUMMARY**



Coasts, as boundaries between land and water, are characterized by the geologic nature of the land, which is unstable and often fragile, and the dynamic power of wind and sea. As a result, coastal environments are constantly changing as they seek to achieve and maintain equilibrium among the many opposing natural forces. The vibrant beauty of shore areas is attracting a growing population; however, the ever-changing character of

coasts makes them hazardous for people and, in the long term, for buildings and structures. The risks associated with living along a coast are comparable to those experienced by people living on a river flood plain, near an earthquake fault, or close to a volcano -- all carry the possibility of eventual catastrophe. Because coastal regions have wide public appeal as places to live, population growth continues to accelerate along the world's coastline. This population explosion superimposed on the dynamic forces acting on coasts is leading to a coastal crisis marked by the following concerns:

Coastal erosion at widely varying rates affects about 90 percent of the world's coasts and is likely to increase due to rising sea levels and increased storm activity.

During the past 200 years, more than half of the wetlands in the United States have been lost due to a combination of natural processes and human engineering. Such loss of valuable wetlands is occurring worldwide, especially in deltaic regions.

Pollution of coastal areas has forced the closing of one-third of the shellfish beds around the United States, has restricted beach use, and has seriously contaminated ground water in some coastal communities. Coastal

pollution is wide spread around the globe, especially near urban centers where sewage treatment is inadequate and ocean dumping of wastes still occurs.

In many coastal urban areas, hard-mineral resources such as sand and gravel for construction aggregate and beach nourishment are no longer readily available onshore. Mining of beach sand accelerates coastal erosion. Offshore marine sand deposits may provide alternative sand resources, but pose environmental and economic dilemmas.

The crisis in the coastal zone is growing worldwide but is especially serious in the United States and many other developed countries in Europe and Asia, where an expanding and more affluent population combined with a variety of government programs over the past 50 years have enabled widespread and often unwise development to take place. If present demographic trends of population growth and expanded development continue, and if sea-level rise and increased storm intensity brought on by climate change global warming also occurs as predicted, stress on the world's coastal environments will increase substantially over the next 50 years.

Intelligent and planned stewardship of the world's coastal resources requires balancing human needs and expectations with coastal realities. Earth-science information that is based on sound scientific research on the coasts, the way they change position and shape, and the factors influencing their development is critical in any attempt to lessen the conflicts and ease the tensions brought on by competing human goals and natural processes.

Ignorance and continued disregard of the geologic and other physical processes that constantly reshape our coasts are intensifying the collisions between people and nature. Despite historical precedents, catastrophes like hurricanes and tropical cyclones too often catch us unaware and unprepared. As powerful as some recent storms were, they will be surpassed by more powerful storms in the future; population growth and increased development along the coasts suggest that these future storms may cause even more damage and loss of life.

Well-coordinated multidisciplinary scientific efforts are needed to improve our understanding of how coasts form and evolve. A clear understanding of how coastal environments have formed and what natural changes they have undergone in the recent geologic and historic past is critical in predicting with confidence their future character. Many different scientific disciplines must be involved. Many different scientific groups can provide critical expertise in specific fields of research. Cooperation between Federal and State agency as well as academic scientists will ensure that this scientific expertise is applied in site-specific studies to solve the individual problems that make up the coastal crisis. Concerted efforts focused on understanding our coasts require efficient coordination to get maximum return from the limited resources available.

As important as increasing our basic scientific understanding of the earth-science processes affecting coasts is, it is equally important to make this information available to coastal-zone planners, managers, and engineers in forms that they understand and can use. These groups must have adequate, accurate information on coastal processes in order to make decisions, assess risks, and solve problems in an efficient and cost-effective manner.

Some engineering practices and human activities that are incompatible with natural processes and that cause long-term harm to the coast can be modified to lessen their effect. In other cases, erosion mitigation techniques that closely replicate natural processes, such as beach nourishment, sand dune creation, and shoreline restoration, can be used to provide temporary protection. In extreme circumstances of high rates of erosion, abandonment and relocation of communities might be the best long-term alternative for many coastal regions around the world.

Dealing effectively with the present coastal crisis and resolving future conflicts along our coasts will require a combination of solutions that must be based on long-term societal needs and on sound scientific and

technical knowledge, rather than emotional responses to meet short-term needs. Results of scientific investigations must be clearly communicated to coastal planners, engineers, and managers; and, most importantly, to political decision-makers and the public. Only when these diverse groups understand the range of choices available and the costs (social, financial, and environmental) and risks associated with each choice, can prudent and enlightened decisions be made.

## **Introduction**

Coastal zone regions worldwide are reaching a crisis. Threats to coasts and to coastal communities are growing as development, recreation, and waste disposal activities increase, often in conflict with long-term natural processes. Other threats to the world's coasts such as sea-level rise, storm effects, and reductions in sediment transport from the land to the coast result from climate change global warming and the damming of rivers. Many of these threats to coastal regions are likely to increase in the near future.

The impending crisis of our coasts stems from misconceptions about what coasts are, how they function and from human actions based on those misconceptions. Differences between our perceptions and the reality of coasts intensify the conflicts between people and nature. These conflicts will worsen as the coastal population expands and competing uses of the recreational, wildlife, shipping, and mineral resources of coasts increase.

## **Perception and Reality**

We think of land as stable and treat it as a permanent asset. For most land, this premise is reasonable because land generally changes very slowly in human terms. Although tectonic and geologic processes, such as plate tectonics and erosion, are always at work, they usually result in very gradual changes that are often barely noticeable during a human lifetime.

Coasts, however, are not static; they are dynamic landforms. They quickly can change shape and location in response to natural forces and human activities. These forces and activities continually act on and influence coasts -- sometimes in the same direction, but often in opposite directions. As a result, the shape and position of the coastline changes. Sand and other sedimentary materials are moved onto and off of beaches by currents, winds, and waves. Seasonal movement of littoral sands creates broad summer beaches followed by narrow winter beaches in an annual cycle. During major storms, huge waves and storm surges can move large amounts of coastal sediments and can flood vast areas in a matter of hours.

On a larger scale, the coast itself moves as it tries to achieve equilibrium with the forces acting on it. Barrier islands and offshore sand bars move landward and along the coast, driven by longshore currents and sea-level rise. Headlands are eroded, moving the coast landward. Sediment is deposited on river deltas, extending the coast seaward. Coastlines also move in response to changes in sea level; even if the land remains stationary, a rise in sea level will move the coastline inland over decades and centuries by inundation and erosion.

## **People vs. Nature**

Because humans too often treat the coast like other parts of the landscape -- as a stable platform on which to safely and easily build -- some of our actions directly conflict with the dynamic nature of coasts. Other human activities, such as the increasing buildup of atmospheric greenhouse gases, may indirectly affect the coasts through global warming, causing worldwide sea-level rise as glaciers and grounded ice sheets melt.

Still other actions, such as the damming of rivers for flood control and water management, may affect the stability of coastlines by restricting the supply of new sediments being carried to the coasts.

Conflicts between people and nature have always existed along the coasts. The increasing desirability and accessibility of coasts as places to work and live have intensified these conflicts greatly over the past 50 years. These conflicts are especially evident in the United States and other developed countries, but are becoming more common worldwide. For example in the U.S., the 1990 census shows that 25 of the 30 coastal States have had dramatic population increases in the past two decades. Coastal areas across the United States now have population densities five times the national average. Currently, 50 percent of the U.S. population lives within 75 kilometers of a coast; this number is projected to increase to 75 percent by the year 2010. These population figures are similar for other regions of the world. As the coastal population grows, so does the need for additional facilities for housing, transportation, recreation, potable water, and waste disposal. Pollution is already severe near some large coastal urban areas and has hurt the fishing industry and caused serious environmental problems.

Wetlands and marshes worldwide are now widely recognized as important but fragile parts of the coastal environment. In the United States, Louisiana, which contains more than 40 percent of the tidal wetlands in the 48 conterminous United States, is losing as much as 100 square kilometers of wetlands each year due to a complex combination of natural and man-made processes. These marshes are one of the world's most productive ecosystems. Their continued demise seriously affects migratory waterfowl, bird populations, and fish and shellfish resources, as well as the coastal culture of Louisiana. Similar loss of wetlands is occurring in many other deltaic regions of the world.

## **The Need for Geoscience Information**

How should we deal with these competing needs? How can we manage the coastal resources? The first step is to understand our coasts better, to build a solid foundation of earth-science data on coastal processes and evolution, and to identify what factors are important in quantitatively determining the location and movement of coasts. Only after thorough research and interpretation can the critical scientific results be translated into practical terms and be incorporated into sound coastal management policies.

## **Coastal Landforms**

Coasts are the dynamic junction of water, air, and land. Winds and waves, tides and currents, migrating sand dunes and mud flats, a variety of plant and animal life -- all combine to form our ever-changing coasts. Their dynamic nature results in their great diversity. Most of us envision a coast as a broad stretch of sand with frothy surf breaking along the shore; in fact, many types of coasts are found, ranging from sandy beaches to rocky shores to coral reefs to coastal wetlands. Some examples from are described below.

## **Rocky Coasts**

Rocky shores form on high-energy coasts where mountains meet the sea and at the base of sea cliffs. Active tectonic environments, such as California and the Pacific coast of South America, produce rocky coasts as a result of mountain-building processes, faulting, and earthquakes. Rocky coasts also form where ice and strong waves have effectively removed fine-grained sediment. In Alaska and parts of Scandinavia, glaciers have scoured most of the sediment cover from the shore. In the Arctic, ice gouging and rafting have removed sand-sized particles from some beaches, leaving cobbles and boulders.

## **Sandy Mainland and Barrier Beaches**

Sandy beaches can be categorized into three types: mainland, pocket, and barrier beaches. Mainland beaches stretch unbroken for many miles along the edges of major landmasses. Some are low standing and prone to flooding; others are backed by steep headlands. They receive sediment from nearby rivers and eroding bluffs. Examples of mainland beaches include coasts of eastern Australia, the Great Lakes, northern New Jersey, and southern California. Pocket beaches form in small bays surrounded by rocky cliffs or headlands. The headlands protect the sandy alcoves from erosion by winter storms and strong currents. Pocket beaches are common in the Mediterranean, New England and the Pacific Northwest. Barrier beaches are found along the Gulf of Mexico, the US east coast, and parts of the North Sea. They are part of complex integrated systems of beaches, dunes, marshes, bays, tidal flats, and inlets. The barrier islands and beaches are constantly migrating, eroding, and building in response to natural processes and human activities.

## **Coastal Wetlands**

Coastal wetlands include swamps and tidal flats, coastal marshes, and bayous. They form in sheltered coastal environments often in conjunction with river deltas, barrier islands, and estuaries. They are rich in wildlife resources and provide nesting grounds and important stopovers for waterfowl and migratory birds as well as spawning areas and valuable habitats for commercial and recreational fish.

Most of the U.S.'s coastal wetlands are in Louisiana, along the Mississippi River and its active and ancient deltas, and in Alaska, at the mouths of the Yukon and Kuskokwim Rivers. The Great Lakes and the southeastern seaboard are fringed by other important wetlands, such as Florida's Everglades. Coastal wetlands can be dominated by salt water, as along the gulf coast of Louisiana, or they can contain a complex and changing mixture of salt and fresh water, like the estuaries of the Chesapeake, Galveston, and San Francisco Bays.

## **Coral Reefs**

Coral reefs abound along the southern coast of Florida and around the Hawaiian Islands, Puerto Rico, the Virgin Islands, and most of the Pacific Islands. In the shallow waters off tropical isles, living coral organisms build reefs that provide important wildlife habitats and protect coasts from waves and storms. Healthy coral reefs are also an important source of carbonate sediment for tropical beaches. Raised coral platforms no longer inhabited by living coral provide coastal materials and form islands such as the Florida Keys.

## **Coastal Change**

Diverse and complex natural processes continually change coasts physically, chemically, and biologically, at scales that range from microscopic (grains of sand) to global (eustatic changes in sea level). Regional and local characteristics of coasts control the differing interactions and relative importance of these natural processes. Human activity adds yet another dimension to coastal change by modifying and disturbing, both directly and indirectly, the coastal environments and the natural processes of change. Earth-science research on coastal dynamics can quantify these changes and improve our ability to predict coastal responses to human actions.

## **Natural Processes**

Coastal lands and sediments are constantly in motion. Breaking waves move sand along the coast, eroding sand in one area and depositing it on an adjacent beach. Tidal cycles bring sand onto the beach and carry it back into the surf. Rivers carry sediment to the coast and build deltas into the open water. Storms cause deep erosion in one area and leave thick washover deposits in another. Plants retain sediment in wetlands and impede movement of coastal dunes. Natural processes that change the water level also affect coastal dynamics. Taken individually, each natural process of coastal transport is complex; taken collectively, they create an extraordinarily intricate system that attempts to achieve a dynamic balance.

## **Waves, Tides, and Weather**

Winds create waves that ripple across the surface of lakes and seas until they drag on the shallow bottom and break onto the shore. In many areas, prevailing winds produce waves that consistently approach the coast at oblique angles. Even the slightest angle between the land and the waves will create currents that transport sediment along the shore. These longshore currents are a primary agent of coastal movement; they are a major cause of sand migration along barrier and mainland beaches.

Tides ebb and flood in response to the gravitational attraction of the moon and sun; exceptional high and low tides occur each month when the sun and moon are aligned. Tides help determine where the waves break -- low on the beach at low tide, high on the beach at high tide -- and, therefore, where sand is transported, deposited and eroded. Rip tides, or undertow, occur periodically along most beaches and can move significant amounts of sand offshore.

Storm systems that move along coasts contain high winds, create large waves, and cause storm surges that raise water levels as much as 7 meters above normal. Although storms are sporadic, they are the primary cause of sediment transport and beach erosion along many coasts. Storms carry sand seaward, forming offshore bars; much of this sand migrates landward during calm weather. Some areas are more storm prone than others. Storms often are concentrated in specific seasons; along the eastern seaboard of the United States, for example, hurricanes occur in the late summer and early fall, and slow moving but very powerful nor' east storms are especially frequent during the winter months. These seasonal trends result in a general difference between the winter "eroding" beach and the summer "building" beach that is so common for most of the world's coasts.

## **Sea-Level and Lake-Level Changes**

In addition to the daily cycles of tides, many other forces lead to significant changes in water level. Predominantly closed bodies of water such as lakes experience dramatic water-level changes in response to precipitation, spring snowmelt, and evaporation. A prolonged period of wet weather in Utah in the early 1980's, for example, raised the Great Salt Lake's water level to record highs, flooding parts of Salt Lake City.

Other local changes in water level occur when the land either rises or falls relative to the water. Along tectonically active coasts, such as the coast of earthquake-prone southern California, land may rise as much as 4 centimeters per century. In recently abandoned deltas, such as near the mouth of the Mississippi River, compaction of newly deposited sediment results in extensive land subsidence (as much as 1 meter per century). The Earth's crust in parts of Scandinavia, Alaska and the Great Lakes area, which was pressed down by the weight of the massive ice sheets that blanketed the north during the last great Ice Age, is now rising due to the retreat of the glaciers. In southeastern Hudson's Bay, Canada, this crustal rebound is raising

vast areas of land at rates as high as 4 meters per century; rates along Lake Superior's north shore reach 60 centimeters per century.

Global changes in sea level result from tectonic processes, such as the down- or up-warping of the ocean basins, or from changes in the total volume of water in the oceans. During the last great ice age, which began 36,000 years ago, huge amounts of ocean water were transformed into glaciers, resulting in a 100-meter drop in the global sea level. We are still emerging from that ice age, and sea level has been rising at highly variable rates over the last 20,000 years; during the past century, the rate of sea level rise has averaged 10-15 centimeters per century worldwide. Recent studies on climate change suggest that sea level could rise world-wide as much as 1 meter over the next century. Sea-level rise of this magnitude would have grave implications for all low relief regions and island nations around the world.

The slope of a coast is critical to determining how water-level changes will affect it. Steeply sloping coasts experience small shifts in their coastlines as the water level changes; however, because wave action along steep coasts is concentrated within a narrow zone, small water-level increases can result in significant erosion of bluffs or dunes. On a gently sloping coast like around the Gulf of Mexico, small changes in water level cause the coastline to retreat dramatically.

## **Coastal Vegetation**

Rooted plants flourish along the shores of bays, estuaries, deltas, and other coastal environments that are protected from the full fury of pounding waves. Plants stabilize dunes through root networks. They build and maintain marshes by catching and retaining in their roots the fine sediment carried by the water. Their natural decay cycle further enriches coastal soils and sediment with decomposing plant matter. Differences in weather regimes, tidal depth, and water salinity determine which plant populations will thrive in a given coastal environment.

A large variety of plant species occurs in coastal areas where tides are extreme, since some plants require total submergence, some tolerate cyclical submergence and aeration, and others flourish in environments that remain dry except at the highest tides. Diversity of species is greatest where water salinity is low. Those few plant species that live in the most saline water have developed ways to control the internal osmotic pressure of their cells.

Gradual changes in weather patterns, salinity, tidal action, and sea level allow normal plant succession to occur in protected coastal environments. Abrupt changes in these conditions often result in widespread destruction of plant communities and the loss of sediment being held by their roots. For example, erosion of barrier islands can lead to saltwater intrusion and increased wave action, which kills plants and destroys the wetlands behind the islands.

## **Local Conditions**

While the same dynamic processes cause continuous change on every coast, coasts do not all respond in the same way. Interactions among the different processes and the degree to which a particular process controls change depend upon local factors. They include the coast's proximity to sediment-laden rivers and tectonic activity, the topography and composition of the land, the prevailing wind and weather patterns, and the configuration of the coastline and nearshore geometry. Earth-science research is showing that these local conditions determine not only the changes to the coast but also the type of coast produced.

## **Mainland Beaches (Southern California)**

The mainland beaches of southern California border an active tectonic region of fault-bounded crustal blocks with high elevations. Ancient shoreline terraces hundreds of meters above present sea level are evidence of rapid and extensive crustal uplift along the coast. The narrow offshore continental shelf is cut by numerous submarine canyons and bordered by deep ocean basins. The weather is temperate year round, but winter storms often dramatically reshape the coast.

The major sediment sources for the beaches of southern California are eroding headlands and adjacent beaches and, to some degree, sediment from local rivers in flood. The major agent of sediment transport along the coast is longshore drift, which moves the sand southward. Submarine canyons in some areas are so close to the shore that they intercept the longshore drift and funnel beach sand seaward into very deep water. The beaches are relatively steep, resulting in a narrow wave zone between high and low tide. This narrow zone receives the brunt of the waves' pounding, and movement of beach sediment (erosion and deposition) is concentrated within this zone.

## **Barrier Beaches (Atlantic Coast, Gulf of Mexico)**

The east coast of the United States, rimmed by a series of barrier islands and spits, separates the mainland coastal plain from a wide, gently sloping offshore continental shelf. This generally tectonically stable region has a storm and hurricane season during the late summer to winter months; high-wind events such as Hurricane Hugo, which came ashore near Charleston, South Carolina, in 1989 and Hurricane Andrew that impacted Florida in 1992, are not uncommon. Most rivers cutting through the low-lying coastal plain flow slowly to the sea and deposit their sand-sized sediment in bays and estuaries before reaching the coast. The river's suspended load of finer particles settles out in the sounds and bays that are protected by barrier islands and spits.

The major source of new sediment to the barrier beaches of the eastern United States is erosion of the adjacent headlands and beaches, whose sand generally is transported south as a result of longshore currents. Sand transported landward from the inner continental shelf also may contribute to the coast and nearshore sand budget. The gentle slope of the eastern barrier beaches results in widely separated high- and low-tide zones, and wave energy is absorbed along this broad surface.

## **Coastal Wetlands (Louisiana Gulf Coast)**

The gulf coast of Louisiana includes a broad expanse of wetlands sheltered from the wave action of hurricanes and winter storms by low-lying barrier islands. Both the wetlands and their protecting islands have formed as a direct result of the shifting of the Mississippi River delta lobes during the past 7,000 years. The deltaic processes that control the movement of water and sediment have resulted in a system of complex drainage patterns, natural ridges and levees, and offshore barrier beaches -- all of which restrict the advance and encroachment of salt water.

Plant life is vital to building and maintaining wetlands. The coastal Louisiana wetlands are biologically zoned on the basis of the salinity of the water and the fluctuations in water depth, with different plant populations living in different areas. The dependence of these wetlands on the Mississippi River and its distributaries as a direct source of sediment and fresh water leaves them vulnerable to changes in the river



system. Their dependence on barrier islands for protection against waves leaves them vulnerable when the barrier islands are eroded.

## **Lake Shores (Lake Erie)**

Lake Erie is the shallowest of five large interconnected bodies of fresh water, known collectively as the Great Lakes that form part of the U.S. Canada border. The basins of the Great Lakes were carved by continental glaciers during the last great ice age and filled with melt waters as the glaciers retreated northward.

Wave and tide action are generally limited in lakes because they are relatively small bodies of water. However, due to Lake Erie's size and oblong shape, communities at the ends of the lake, like Buffalo and Toledo, suffer from dangerous storm surges. These storm surges can quickly raise the local lake level by more than a meter. Though they may last only a few hours, surges can do considerable damage, primarily from flooding.

Much of Lake Erie and its beaches and cliffs are frozen during winter, inhibiting the formation of storm waves and reducing erosion. However, during ice formation in early winter and during the spring thaw, ice processes can accelerate erosion. The spring rains, snowmelt, and low evaporation rates cause Lake Erie's average water level in June to be more than 30 centimeters above the typical January level. Several years of above-normal precipitation, as in the mid-1980's, can cause Lake Erie's water level to rise significantly above its long-term average, increasing the likelihood of flooding and erosion.

## **Human Interventions**

Human activities add another layer of complexity to the natural processes of coastal lands and materials. These activities may have direct or indirect effects on our changing coasts. They may affect sources of new sediment to the coast and the movement of sediment within the coastal environment; they may promote changes in sea level, both local and global.

People's activities are often conducted without an adequate understanding of coastal geology and processes. As a result, they can lead to unforeseen degradation of coasts. Even human actions intended to save or improve the coast may inadvertently increase erosion. Cooperative scientific investigations are starting to provide the crucial information needed to minimize the unintended effects of human disturbances along coasts.

## **Sediment Starvation**

For some coastal regions, such as the US Pacific coast, rivers supply a large part of the coastal sediment budget. Dams built for flood control and water catchments along the rivers leading to these coasts inhibit the transport of large-grained sediments. Lacking new material, the sediment-starved coasts erode and migrate inland. Damming of tributary rivers to the Mississippi River over the past 60 years has also reduced the movement of sediment. Studies by the U.S. Geological Survey (USGS) in recent years demonstrate that the amount of sediment carried by the Mississippi has been cut in half, aggravating the deterioration of Louisiana's wetlands.

An important source of sediment to Louisiana's deltaic wetlands was periodic flooding of the Mississippi River, which deposited new material on the flood plain. Massive levees built along the riverbanks now contain these floods and eliminate the supply of sediment to the wetlands. As a result, the natural compaction and subsidence of the delta are no longer balanced by the deposition of new sediment, and the relative local sea level is rising as much as 1 centimeter per year. Sediment-laden water, retained by levees along the Mississippi River, deposits its load into deep water at the mouth of the delta, where most of the sediment is lost to the coastal environment. To counteract the effects of past dam building and river channel modifications structures are being built to divert fresh water from the Mississippi River to adjacent wetlands. These engineering works are expensive and the long-term benefits are uncertain.

Attempts to counter sediment starvation along severely eroding coasts have included the artificial replenishment of beach material by placing sand directly onto the beach. Beach nourishment is not a permanent solution and is expensive, but in some regions it can be cost effective. The lack of clean sand suitable for fill often limits beach nourishment programs, but offshore surveys can sometimes locate sand bodies for dredging and transport to the beach. A few beach replenishment programs have had long-term positive effects. Typically, beach nourishment projects are not effective long-term solutions for erosion. For the U.S. east coast half of the replenished beaches lasted 2 years or less.

## **Pollution**

As the number of active landfills dwindles and coastal populations grow, offshore waste dumping and coastal pollution increase. This additional dumping increases the possibility of improper waste disposal polluting the coastal environment. Living coral reefs are particularly vulnerable to pollution, but other coastal environments suffer as well. Fishing industries have also been severely damaged by coastal pollution; more than one-third of the U.S.'s shellfish beds are closed or restricted as a result of contamination.

## **Sediment Trapping**

The natural movement of sand is at best a nuisance for owners of beachfront property. When this movement results in a net loss of sand from the beach, owners may consider the natural process as a serious threat. To prevent beach loss, groins are often constructed out into the water. These solid structures impede the littoral drift of sand caused by longshore currents. The beach then expands on the updrift side of the groin; however, the downdrift side of the groin loses sand because of continuing longshore movement. Small groins may have little effect on sediment movement along the entire beach. Larger groins or jetties, such as the ones at the southern end of Ocean City, Maryland, and at Cape May, New Jersey, can lead to significant retention of beach sands on the updrift side, but these gains must be balanced against the coastal degradation on the downdrift side of the engineering structures. Sediment carried seaward of the jetty may be deposited as shoals offshore in deeper water and removed from the active coastal sediment budget, further increasing erosion of the adjacent coast.

Seawalls constructed to protect property along retreating beaches often exacerbate beach erosion. They confine the wave energy and intensify the erosion by concentrating the sediment transport processes in an increasingly narrow zone. Eventually, the beach disappears, leaving the seawall directly exposed to the full force of the waves. For example, a massive seawall built to protect a highway and beach houses along the northern New Jersey coast has resulted in the complete disappearance of the beach itself.

## Coastal Degradation

Human actions that lead to the destruction of dune grasses and the disturbance of coastal landforms promote increased erosion and movement of beach materials. Off-road vehicles and foot traffic on sand dunes compact sand, destroying plant roots and animal burrows. Other wildlife habitats, such as nesting and feeding areas for shorebirds, are disturbed by human activity; young birds are especially vulnerable to these disruptions.

Sand dunes help absorb the pounding of high waves and reduce overwash flooding during storms; bulldozing dunes to improve views of the sea destroys this natural protection. Dredging navigation channels and tidal inlets and discharging the material in deep water also remove sediment from the coastal system and interfere with longshore transport. Canals cut in wetlands for navigation, pipelines, and drainage provide channels for salt-water invasion during storms and high tides; the increased salinity often kills marsh plants leading to accelerated land loss and deterioration of wetlands.

## Water Level Changes

Human activities can cause local and possibly global changes in sea level. Pumping of ground water, salt brines, and petroleum resources from coastal environments has led to significant subsidence in many regions; the Texas coast around Galveston Bay has experienced a particularly alarming rise in its relative sea level. The increasing release of greenhouse gases, such as carbon dioxide and methane may promote global warming and accelerate the melting of massive grounded ice sheets in Greenland and Antarctica, consequently raising sea level worldwide.

## Isles Dernieres, Louisiana—Rapidly Eroding Barrier Islands

The Isles Dernieres barrier island chain stretches for 32 kilometers along the coast of Louisiana, about 100 kilometers west of the mouth of the Mississippi River and 120 kilometers southwest of New Orleans. Coastal studies conducted since 1985 by the USGS indicate that the Isles Dernieres are eroding as fast as 20 meters per year. These high erosion rates, caused by both natural forces and human actions, have produced one of the most rapidly deteriorating shorelines in the world.

Geologic investigations during the last 40 years have shown that the low-lying plain and coastal barrier islands of southern Louisiana consist of fine sand and mud deposited by the Mississippi River in four successive delta complexes over the past 7,000 years. Each time the river channel moved to a new position, the combination of natural subsidence and reduction in sediment supply caused erosion and deterioration of the abandoned delta. The Isles Dernieres mark the end of a delta that reached its maximum size about 500 years ago.

By the mid-1800's, the Isles Dernieres were a single rather broad barrier island supporting mature forests and a thriving resort community. A devastating hurricane struck the island in 1856, destroying the resort and killing hundreds of people. Over the past 130 years, natural processes of storm erosion and a rise of more than a meter in relative sea level have dramatically reshaped the Isles Dernieres.



## **UNDERSTANDING THE GEOLOGIC PROCESSES OF COASTAL LAND LOSS FOR THE RESTORATION OF NORTH AMERICA'S LARGEST RIVER DELTA-THE MISSISSIPPI**

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The Mississippi River delta is a vital natural resource to the United States. This resource is at risk of vanishing, between 1932 and 1990 this delta lost over 680,000 acres of critical habitat-swamps, marshes, and barrier islands. Understanding the critical processes of land loss is essential to the rescue of this national treasure. Over the last 20 years the USGS in cooperation with the USACE and Louisiana universities have investigated processes of erosion, submergence, and man's impacts in addition to geologic framework studies of Holocene coastal evolution and sediment resources. This information is key to developing successful restoration strategies and projects. Without the implementation of significant restoration programs the federal and state natural resource trustees predict the economic impact of the coastal land loss crisis will exceed \$ 100 billion by the year 2050. The Coastal Wetland Planning, Protection, and Restoration Act (CWPPRA) of 1990 was a start with \$ 40 million per year dedicated to restoration activities. From CWPPRA successful freshwater diversions, marsh creation, and barrier island restoration projects were implemented. In 1998 the federal and state natural resource trustees realized a larger restoration program was needed to reverse the magnitude of Louisiana's land loss problem. As a result, the Coast 2050 initiative was started to implement the largest coastal restoration program in the U.S., \$ 14 billion through the Water Resources Development Act.